

DETERMINATION OF BENZENE  
IN PETROLEUM DISTILLATES

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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# THE DETERMINATION OF BENZENE IN PETROLEUM DISTILLATES

## A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE

IN

CHEMICAL ENGINEERING

MAY 29, 1919

APPROVED

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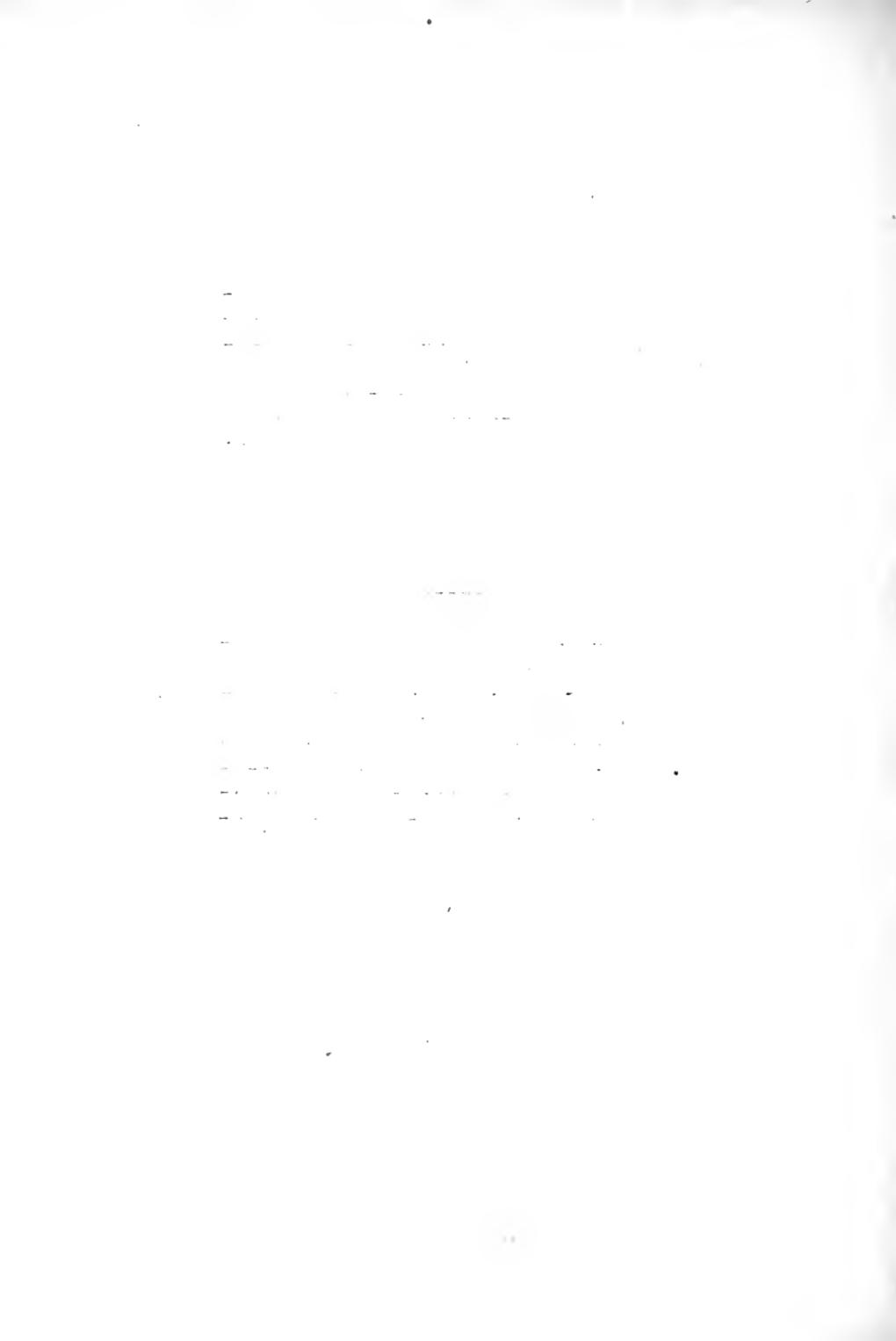
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The object of this work is to find a method of determining benzene in admixtures with paraffin hydrocarbons, which will be rapid and accurate. The lighter distillates of petroleum usually contain a small percentage of benzene, toluene and xylene, of which about 70% is benzene. These aromatic hydrocarbons have also been found among the products from the cracking of heavy petroleum oils. In view of the fact that some successful commercial method will be found for the recovery of benzol from petroleum, or its distillates, this method of determination is to be especially applicable as a rapid commercial laboratory analysis.

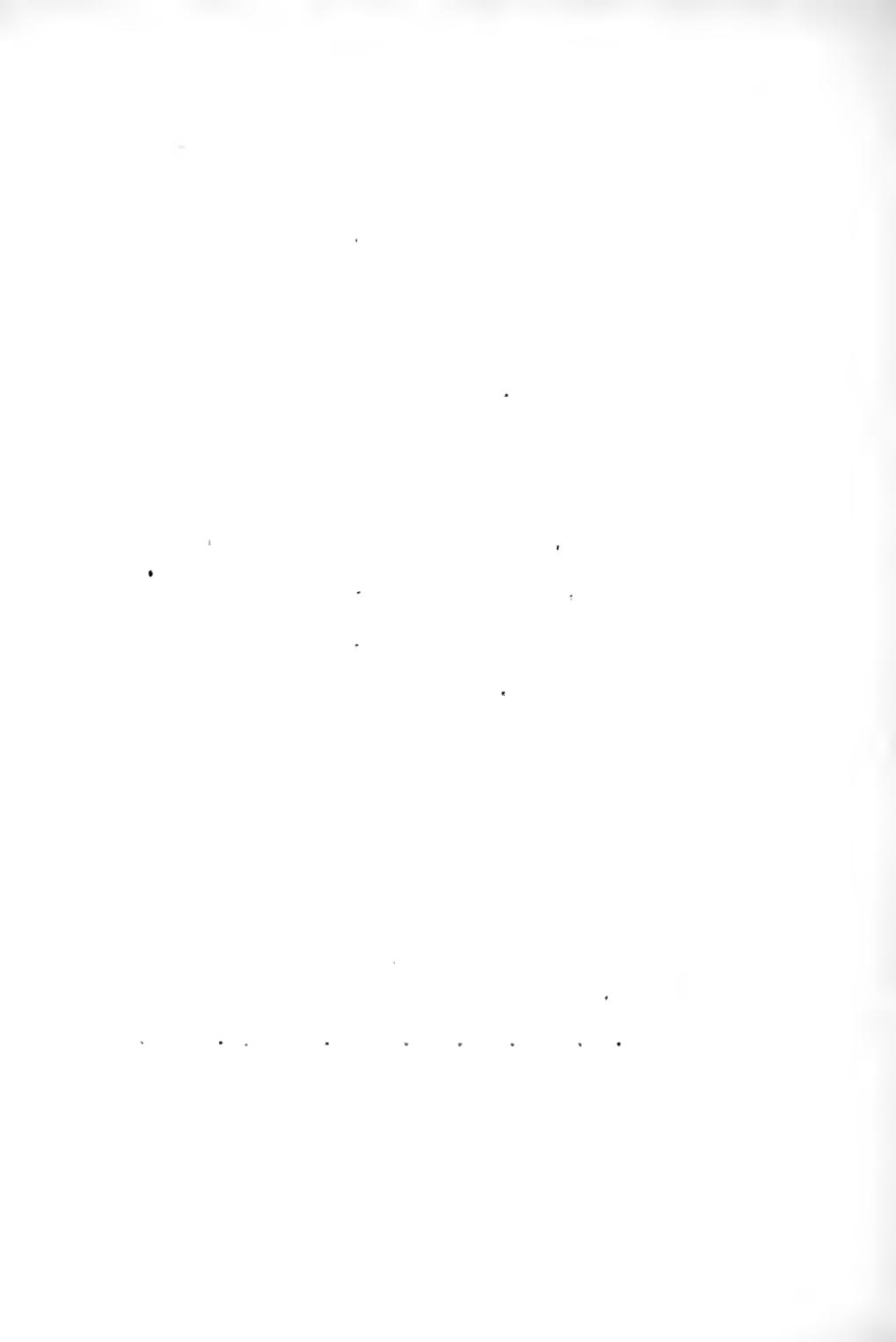


A determination of this kind depends either upon the difference of the physical or chemical properties of the substances involved. Many attempts have been made both on a laboratory and commercial scale on the separation of the aromatic hydrocarbons, of which benzene is the major constituent, from petroleum. None of these plans were very successful, but a few are worth mentioning.

Edleanu<sup>1</sup> developed a commercial process for the refining of petroleum and also the details of a laboratory method of analysis in estimating the aromatic hydrocarbons as impurities in ordinary petroleum mixtures, on the basis of the solubility of

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1) Bull.Am.Inst.Min.Eng. Sept. 1914, P. 2313.



the aromatic hydrocarbons in liquid  $\text{SO}_2$ .

Rittman and Moore<sup>1</sup> summarize this method as follows:

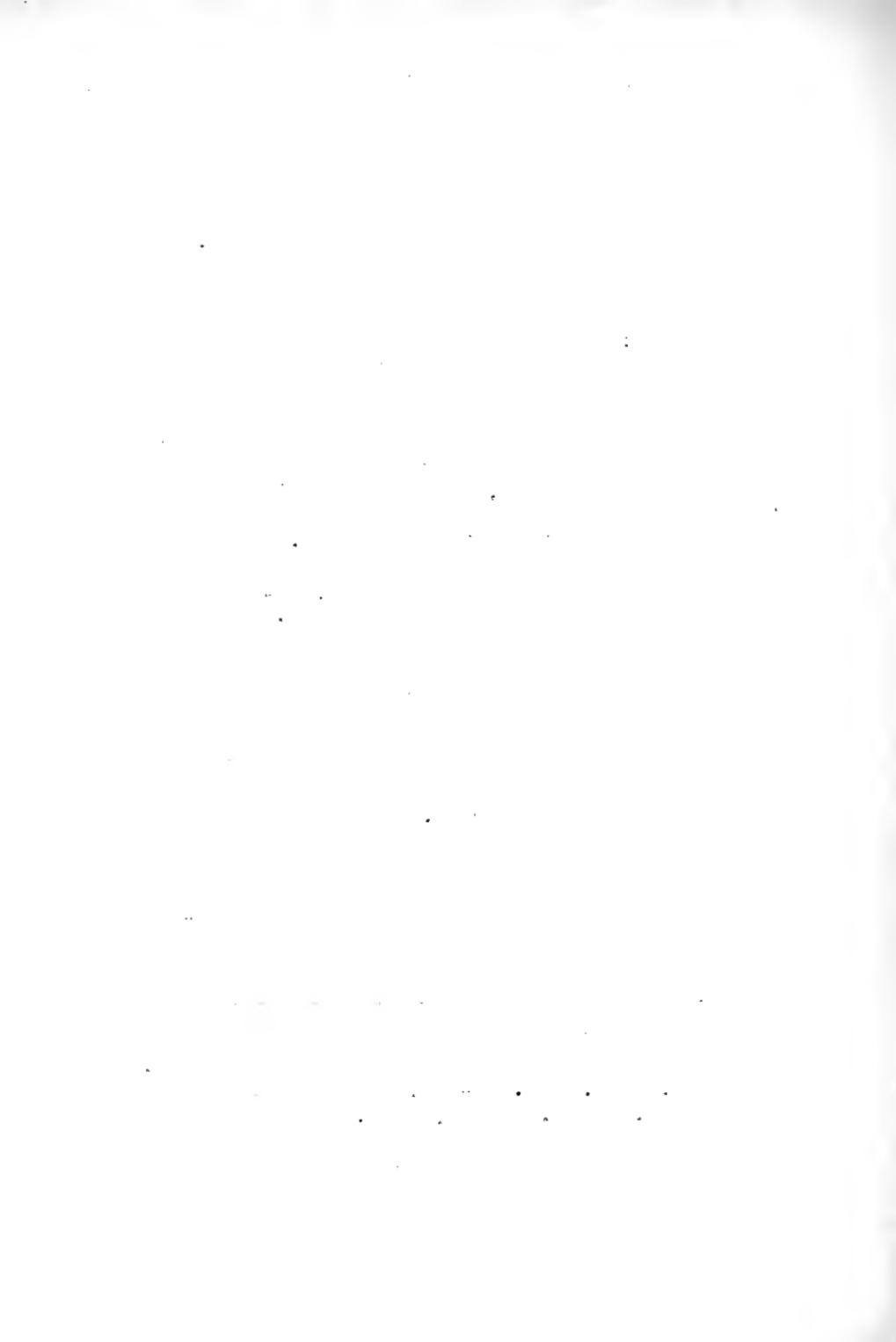
- 1) "It has appeared that although the liquid sulphur dioxide method works well for the estimation of small quantities of aromatics in the hydrocarbon mixtures, it is not applicable if the contents exceed a limit in the neighborhood of 25 per cent.
- 2) Temperature at which extractions are performed must be low, preferably in the neighborhood of  $-20^{\circ}\text{C}$ ."

This method on account of its small range and low temperature requirements is not very practical and convenient for rapid laboratory determination.

Valenta<sup>2</sup> states that aromatic hydrocarbons are soluble in dimethyl sulphate and that open chain hydrocarbons are

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1) "The Range of Applicability of the Liquid Sulphur Dioxide Method for Determining Aromatic Constituents in Hydrocarbon Mixtures." Met. Chem. Eng. 15-713.  
2) Chem. Zeitg. 30-266, 1906.



almost insoluble. Church and Weiss<sup>1</sup> arrived at the conclusion that the dimethyl sulphate test was inaccurate and that dimethyl sulphate is difficult to obtain in a pure state, and is dangerous on account of its poisonous nature.

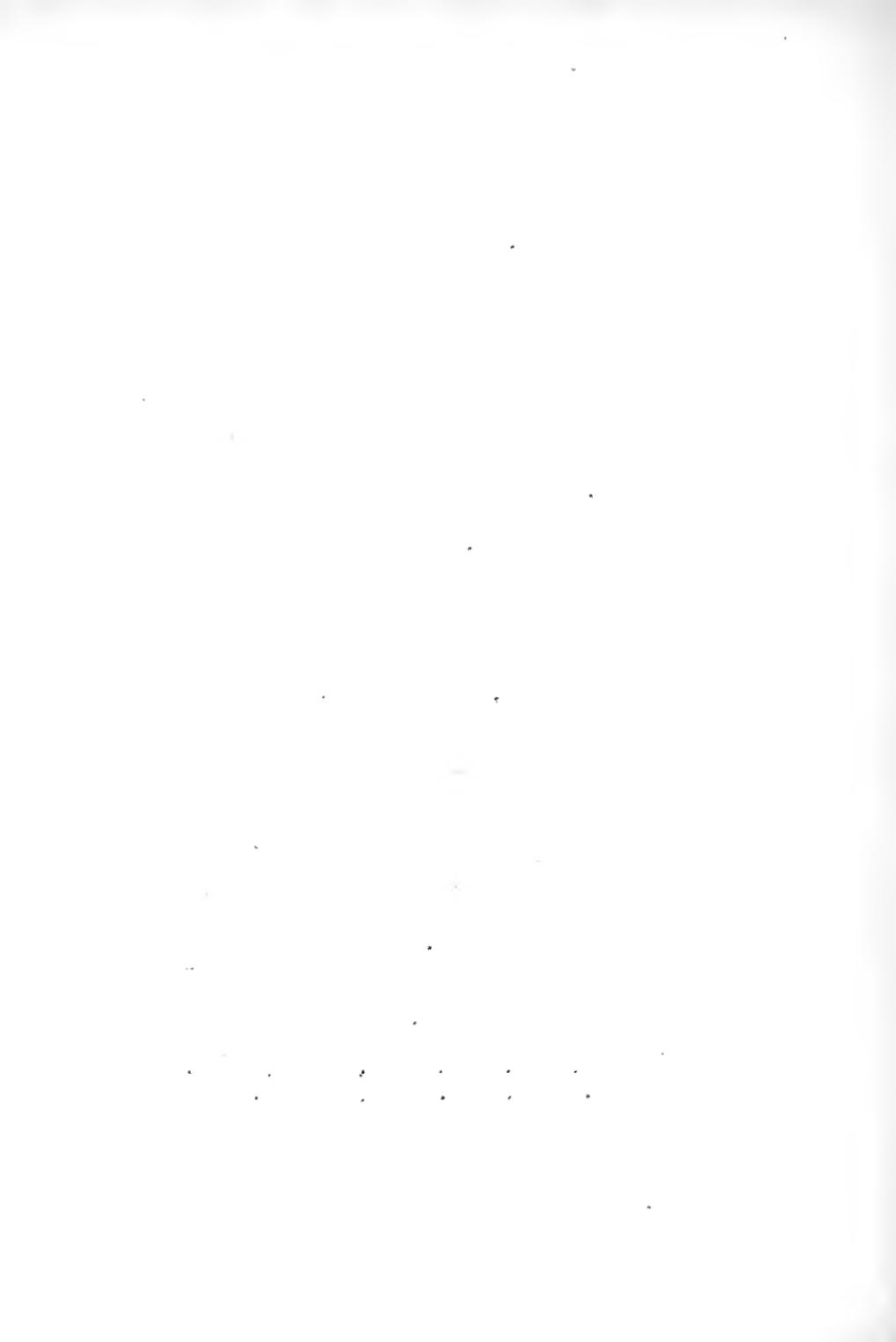
Rittman, Twomey and Egloff<sup>2</sup> have summarized their investigations on "The Estimation of Aromatic Hydrocarbons in Cracked Petroleum," as follows:

"The following conclusions have been reached through the results of a series of experiments performed with a degree of care and accuracy generally feasible in commercial laboratories.

- 1) Solubility methods for the separation and estimation of aromatic compounds in cracked petroleum do not seem to be satisfactory.
- 2) The freezing method for the determination of benzene yields at best only qualitative results.

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1) Jour. Ind. Eng. Chem. 6-396, 1914.  
2) Met. Chem. Eng. 1915, 682-86.



3) Results approximating those of the best chemical methods may be obtained by separating aromatic hydrocarbon with three successive distillations and determining their percentage in distillation cuts by specific gravity relations."

The "best chemical methods" consist of a removal of all unsaturated compounds, followed by the nitration of benzene. This method takes too much time for a commercial analysis and is consequently used only to check results.

This brief survey draws us to the conclusion that benzene, and the aromatic hydrocarbons in general cannot be determined with any degree of accuracy by physical methods. This brings forth the desirability of some suitable chemical process.

A crude oil, or its products, consists mainly of paraffin hydrocarbons, and a small percentage of unsaturated and aromatic hydrocarbons. Let us first make a com-



parison of their chemical properties and their reactions with certain types of reagents:

**Paraffin Hydrocarbons:-** The paraffins are characterized by their inertness. They are insoluble in concentrated sulphuric acid and are not attacked by it. They can be shaken with fuming nitric acid without appreciable change. They resist to a high degree the action of oxidizing agents. Chlorine reacts with the hydrocarbons to form substitution products. The liquid hydrocarbons react slowly with bromine. No action occurs with iodine.

**Ethylene Series (unsaturated hydrocarbons) :-** Due to this unsaturation the olefines are very active. They react readily with sulphuric and nitric acids. They are readily oxidized, and their characteristic reaction is the addition of a halogen.

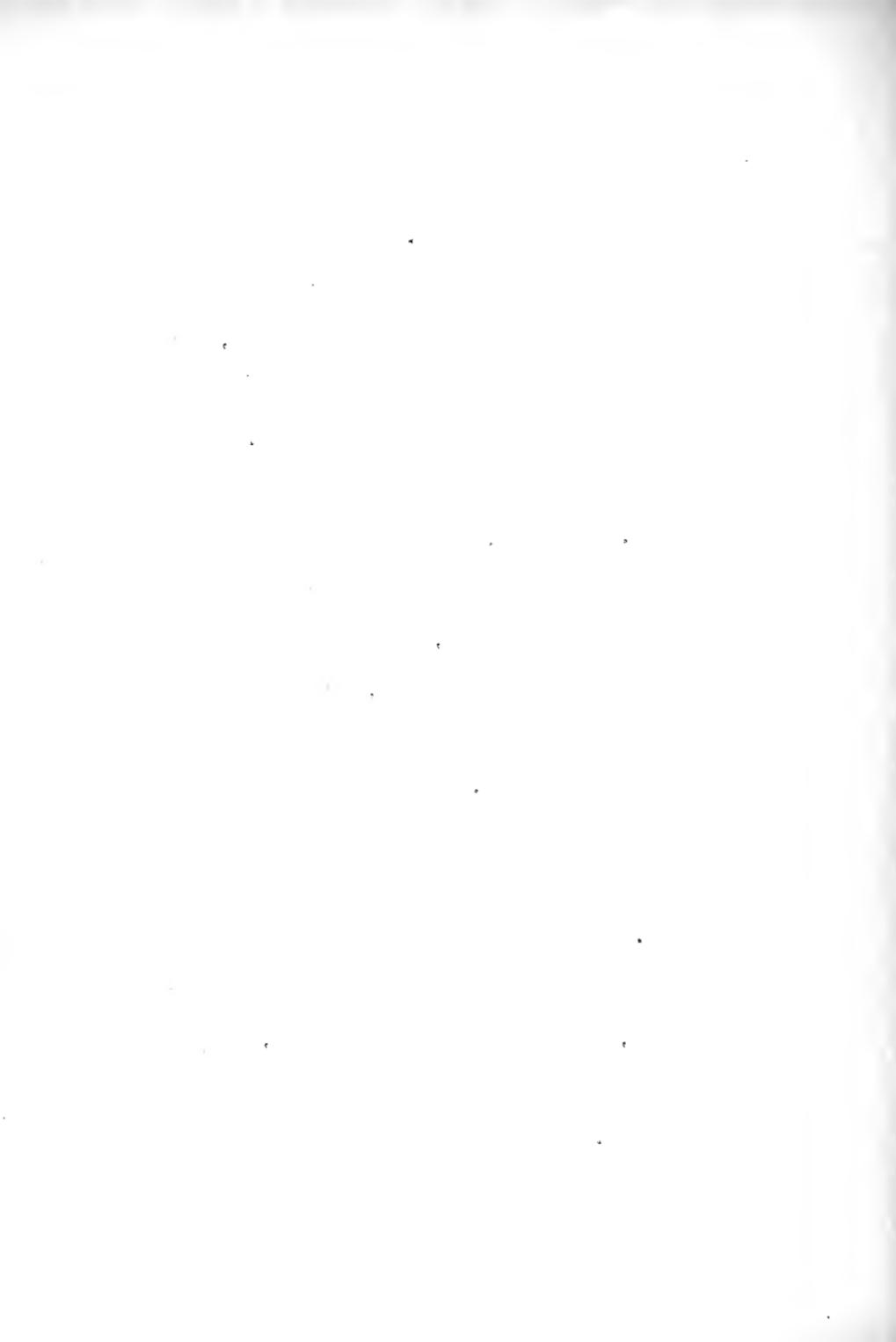
**Benzene Series:-** Benzene is converted to benzene sulphonic acid when heated with concentrated sulphuric acid. When benzene is warmed with concentrated nitric acid, nitrobenzene is formed. Aromatic compounds which contain side chains are easily oxidized by an oxidizing agent. Halogens react with the side chain of the aromatics under the same laws governing straight chain hydrocarbons, but enter only on the ring in the pre-



sence of a carrier.

A close study of the foregoing comparison will reveal that a halogen, especially bromine reacts differently with each of the three characteristic groups. A resume of these reactions will prove this conclusion. Bromine, except under extraordinary conditions will not react with the paraffin hydrocarbons, it forms addition products with the olefines, and forms substitution products with benzene in the presence of a carrier.

The first step is to verify the reactions of bromine with the individual groups. That bromine does not react with the paraffin hydrocarbons under ordinary conditions, with or without a carrier, is self-evident to any one well versed in organic chemistry. Several tests were made to fin-



ally check this and the results were positive. See Table 1. The pure paraffin hydrocarbons were prepared as follows:- The 40-130°C. distillate of a commercial gasoline, was nitrated for 14 hours, the nitrocompounds removed, and the unsaturated bodies removed with successive portions of concentrated sulphuric acid until the acid was only slightly colored. The final product, the paraffin hydrocarbons, was neutralized by washing with a concentrated solution of sodium hydroxide and washed with water, and then dried over calcium chloride crystals.

The bromination of unsaturated hydrocarbons has long been the standard test for the olefines. As given by Allen<sup>1</sup>, this determination is:-

"A 1/10th normal solution of bromine is made by dissolving 2cc. of bromine in

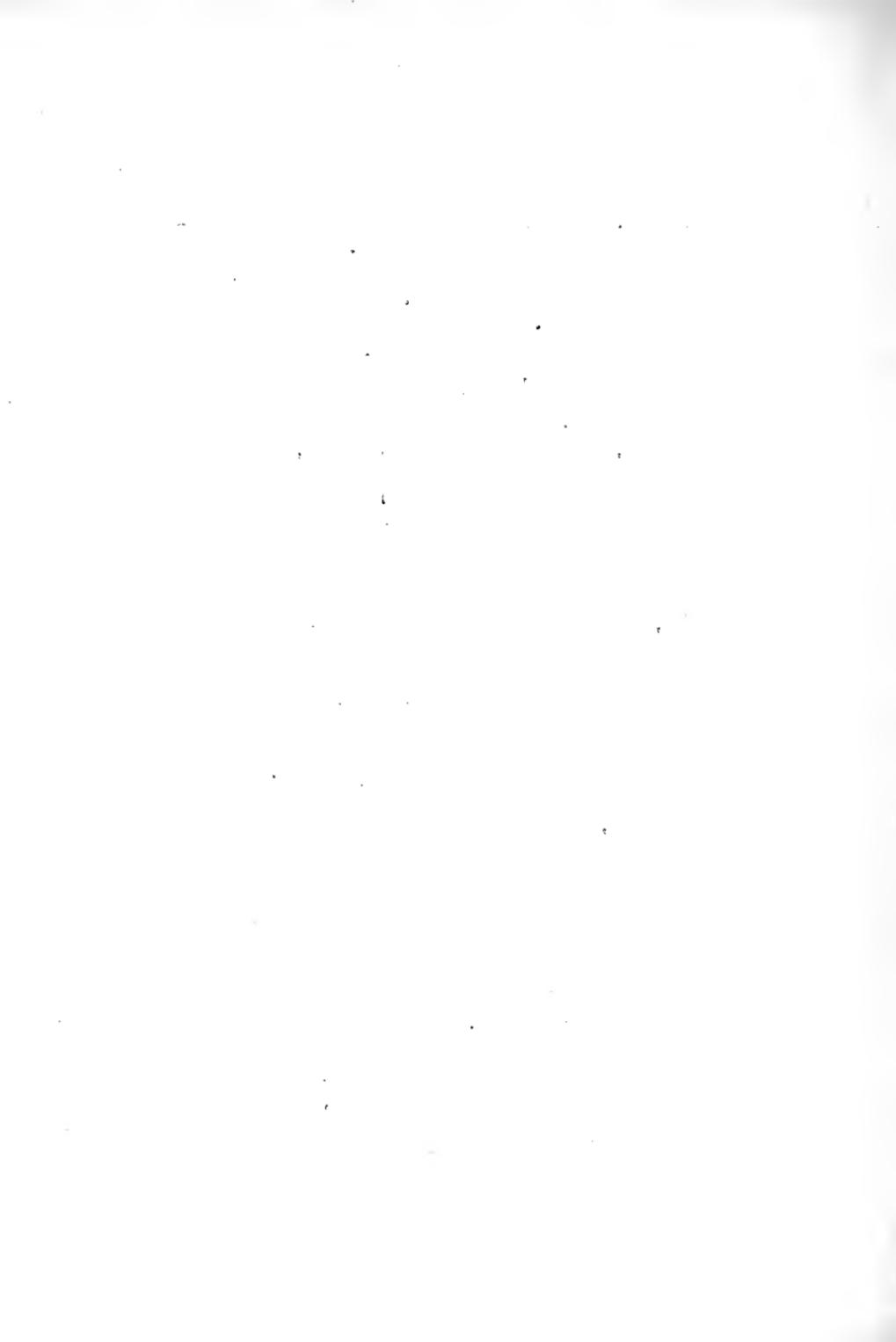
1) Commercial Organic Analysis Vol.11 p.241



750cc. of recently distilled carbon bisulphide and the solution, having been dried by calcium chloride crystals, is preserved in the dark.

From .3 to 1 gram of oil is weighed out in a perfectly dried, stoppered flask or separator, the oil diluted if necessary with carbon bisulphide to about 25cc. Then 25cc. of the bromine solution is added, the flask is stoppered, agitated and left in the dark for 15 minutes. If the liquid is not distinctly red after the agitation, a further quantity of bromine solution is added without delay. After 15 minutes an excess of an aqueous solution of potassium iodine is poured in, and the mixture agitated. The bromine which was not absorbed by the oil having thus been replaced by an equivalent amount of free iodine, the flask is removed to a light place and the contents titrated with a 1/10th normal solution of sodium thiosulphate. The titration is conducted in the usual manner, the final change being rendered more sharp by adding a few drops of starch solution when the carbon bisulphide is nearly decolorized.

The bromine solution used requires to be standardized occasionally by treating 25cc. of bromine solution with potassium iodide solution and titrating exactly as above. The difference between the volume of sodium thiosulphate solution now required, and that used after treating the oil, represents the volume corresponding with the amount of bromine absorbed."

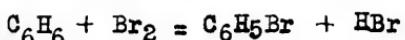


No special tests need be made to verify the above determination as the test is universal.

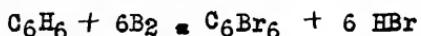
The problem now arises as to the bromination of benzene, namely, the best carrier, the most favorable conditions, and the final products formed. The bromination of benzene, the replacement of a portion of the hydrogen of the aromatic hydrocarbons by bromine, is very easily accomplished by the aid of a carrier, even at low temperatures. The amount of hydrogen substituted depends upon the amount of bromine used, and if the bromination is sufficiently energetic all six atoms of hydrogen of the benzene molecule may be substituted by the bromine. However, even if the theoretical amount of bromine is used, a single bromide is never formed. A portion of the hydrogen is bro-



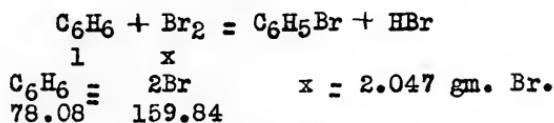
minated a little short of the theoretical action, while another portion is brominated over this amount. The problem is then, to eliminate as much of this error as possible. The simplest reaction of the bromination of benzene is represented thus:



while the highest degree of bromination is:



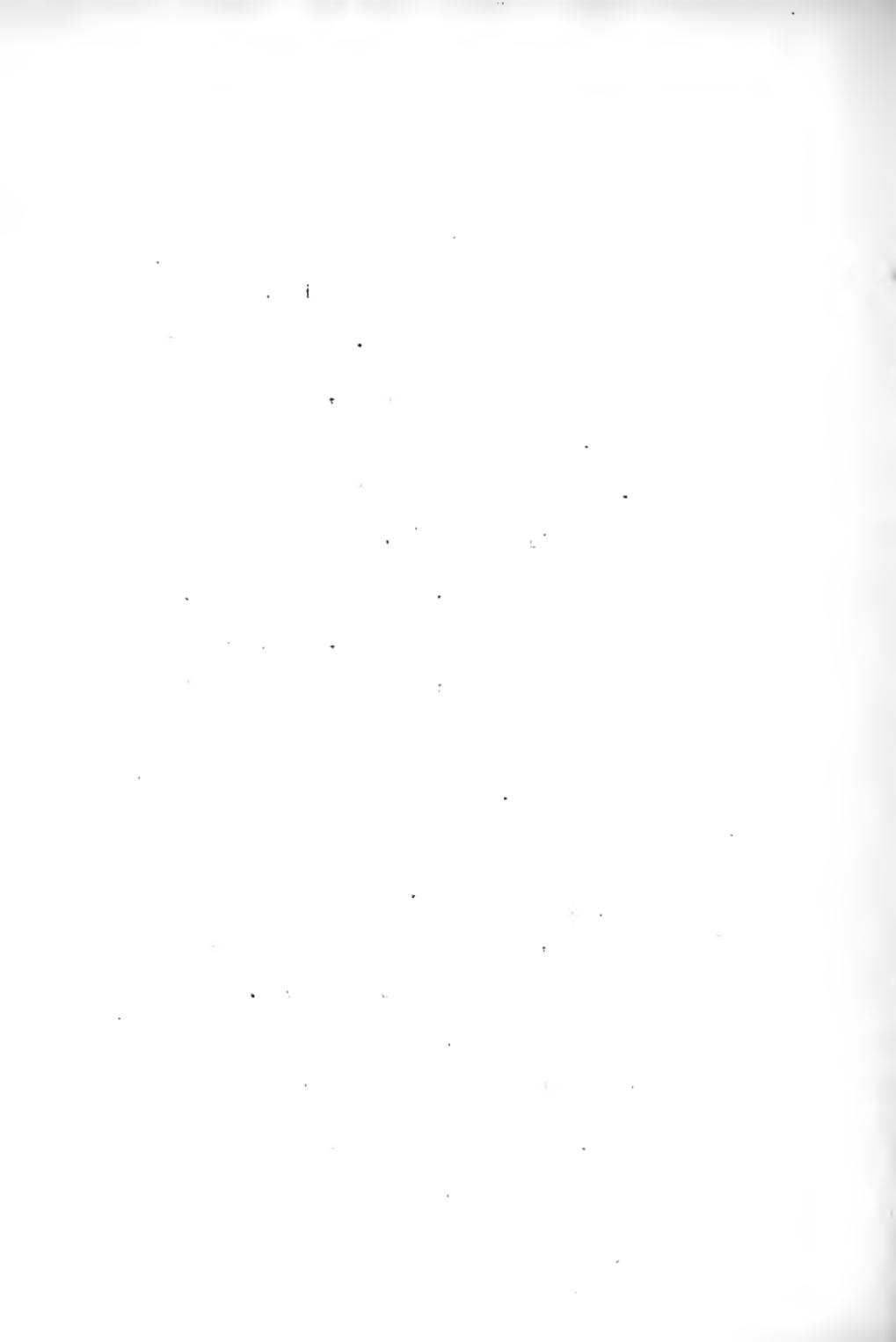
Since the hydrogen atom which is substituted by the bromine atom combines with another bromine atom, it is seen that two bromine atoms, a bromine molecule, must be used for each hydrogen atom substituted.



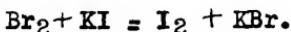
Thus 2.047 gms. of bromine are necessary for each atom of hydrogen substituted in a gram molecule of benzene.



The next question arose as how to combine the benzene and the bromine. The benzene used was 100% benzol. Bromine "per se" is too dangerous to handle, and is also too volatile. So a common solvent should be selected. This solvent should also be a solvent for any oil upon which this determination is to be made. For these reasons, carbon bisulphide was selected. Consequently in all the following determinations the benzene or oil was dissolved in carbon bisulphide, and the bromine added in the form of a standard solution of bromine in carbon bisulphide. The scheme as given by Allen, on page 7 was adopted for determining the bromine not absorbed. A 10% excess of an aqueous solution of potassium iodide is added and the mixture well shaken. The unabsorbed bromine then



reacts with the potassium iodide liberating an equivalent amount of free iodine:



The free iodine is then titrated with a standard solution of sodium thiosulphate, the end point being rendered more distinct by adding a few cubic centimeters of starch solution before the reaction is completed:



Let us next consider the selection of a proper carrier. For a short and complete discussion concerning carriers,

Gatterman<sup>1</sup> is quoted:

"The introduction of bromine can be essentially facilitated by the use of a so-called bromine carrier. As such the bromides of metalloids, or metals are used: 1) either in the

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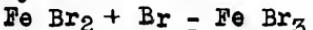
1) Gatterman's "The Practical Methods of Organic Chemistry," translated by Schober and Babasinian, p. 273.

Y<sub>2</sub>

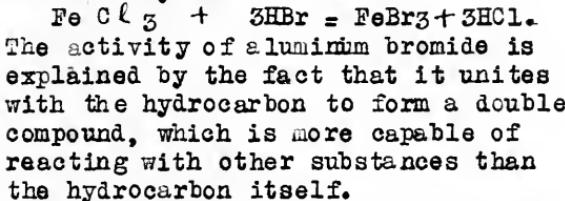
already prepared condition, or, 2) they can be generated from their elements in the reaction. To the first class belong ferric bromide and aluminum bromide. The action of ferric bromide depends on the fact that on being reduced to ferrous bromide, it yields bromine in 'statu nascendi':



Since the ferrous bromide unites with bromine again, to form ferric bromide, a small quantity of this has the power to transfer an indefinitely large quantity of bromine:



Instead of ferric bromide, ferrous bromide or anhydrous ferric chloride may be used. The latter decomposes with hydrobromic acid to ferric bromide and hydrochloric acid:



To the second class belong iodine, sulphur, phosphorus, iron, aluminium, etc. If these elements are added to the brominating mixture, the corresponding bromides are formed, e.g.:



While these give up all their bromine, or a portion of it, as is the case with ferric bromide, in the atomic condition, the residue again



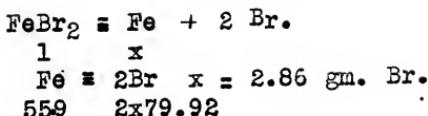
unites with bromine, and as above, a small quantity of the carrier may transfer large quantities of atomic bromine."

It is a well know fact that of these iron is the best carrier. Consequently iron was selected and a series of tests made. The powdered iron was weighed out, introduced into a glass stoppered bottle and a known amount of standard bromine solution added. After 1/2 hour the stopper was removed, an excess of potassium iodide solution added, the contents well agitated and the excess bromine titrated with a standard sodium thiosulphate solution. The results are given in Table II.

As the final product is ferrous bromide, the theoretical amount of bromine which the iron combines with can easily be calculated. For every atom of iron



two atoms of bromine are needed:

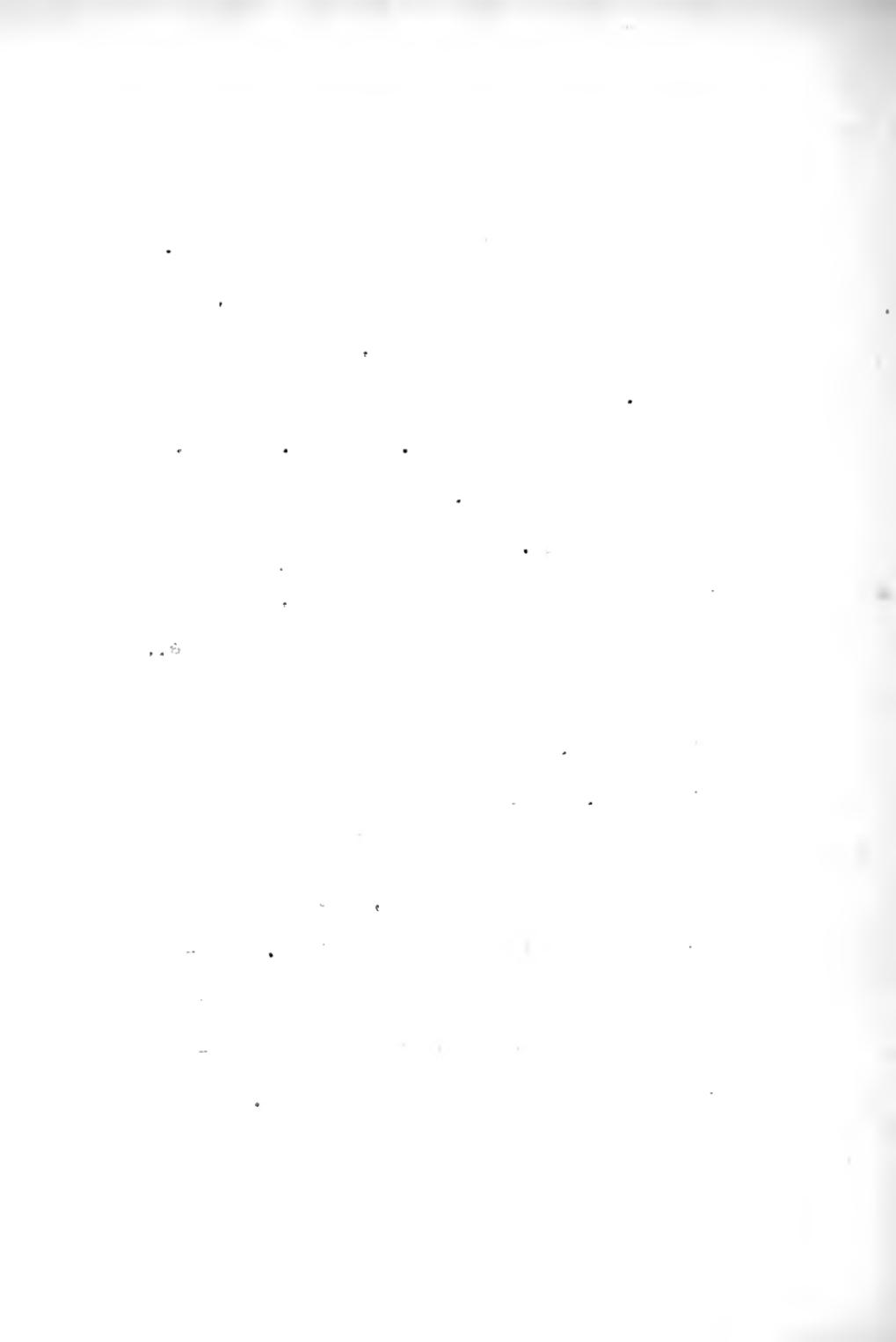


Therefore 2.86 gm. of bromine are necessary for every gram of iron. The results show that only 4.5 per cent of the 60 mesh iron was converted into the bromide, while 77.8 per cent of the 100 mesh iron, and 98. per cent of the 200 mesh iron was converted. This resulted in the selection of the 200 mesh iron, an arbitrary amount of .02 gm. to be used for each determination.

To eliminate the weighing of the iron necessary for each test the author tried other carriers, all compounds of iron with the following results. Ferrous bromide could not be obtained pure enough

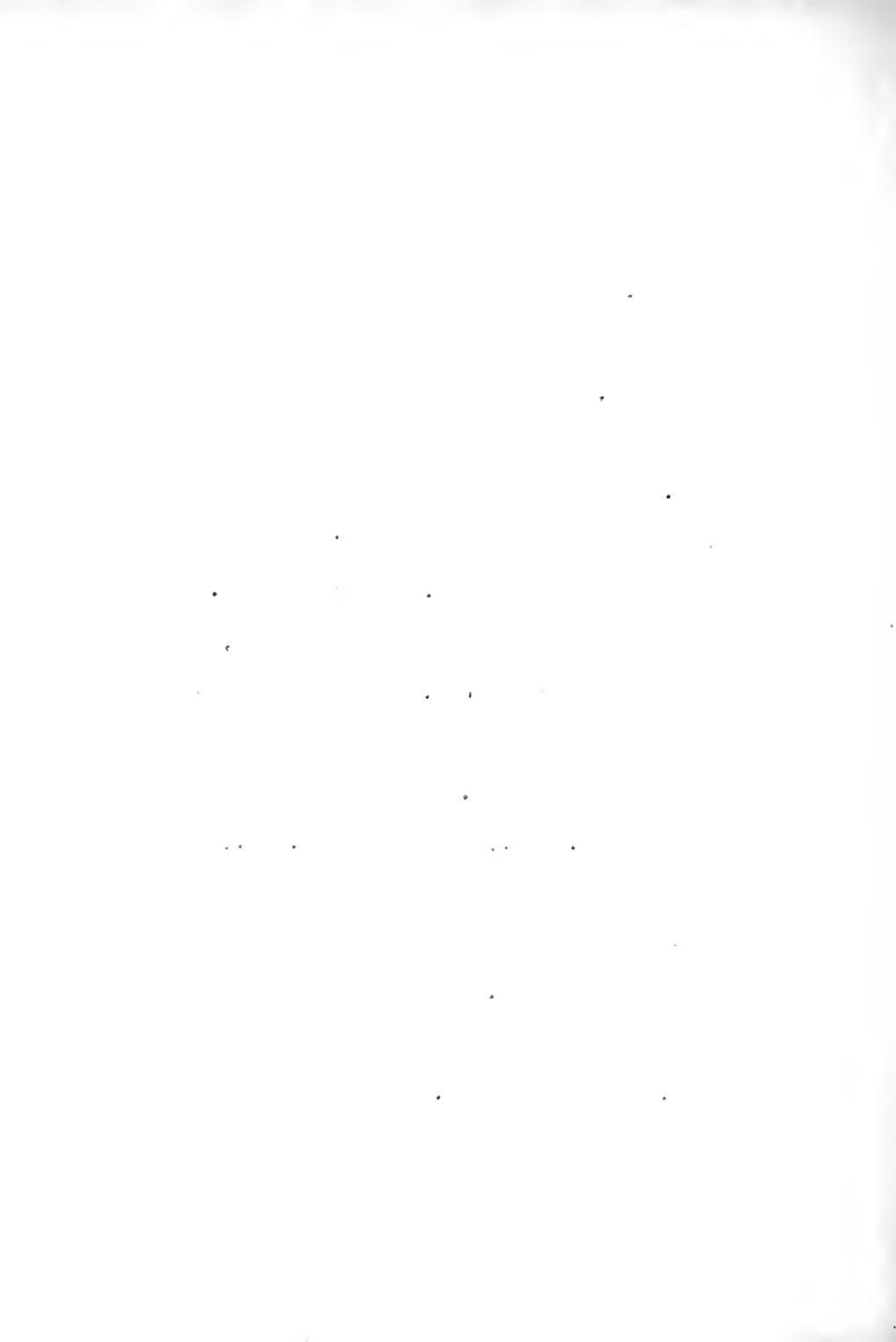


to warrant using with any success whatever. The use of ferrous bromide in solution, various solvents being used, also proved a failure. Ferrous bromide was only soluble in  $\text{CS}_2$  to the extent of .00137 gm. per cc. of carbon bisulphide. This proved to be too small an amount. Ferrous bromide is infinitely soluble in ethyl alcohol, and the alcohol and carbon bisulphide are miscible,, but the alcohol is oxidized by the sodium thiosulphate. Therefore this method is eliminated. Ferrous bromide is soluble in water to the extent of 102 parts per 100 parts of water at  $0^{\circ}\text{C}.$ , but water and carbon bisulphide are not miscible. Consequently there is not sufficient contact between the ferrous bromide and the bromine and benzene to warrant success. Failures in these methods necessitated the



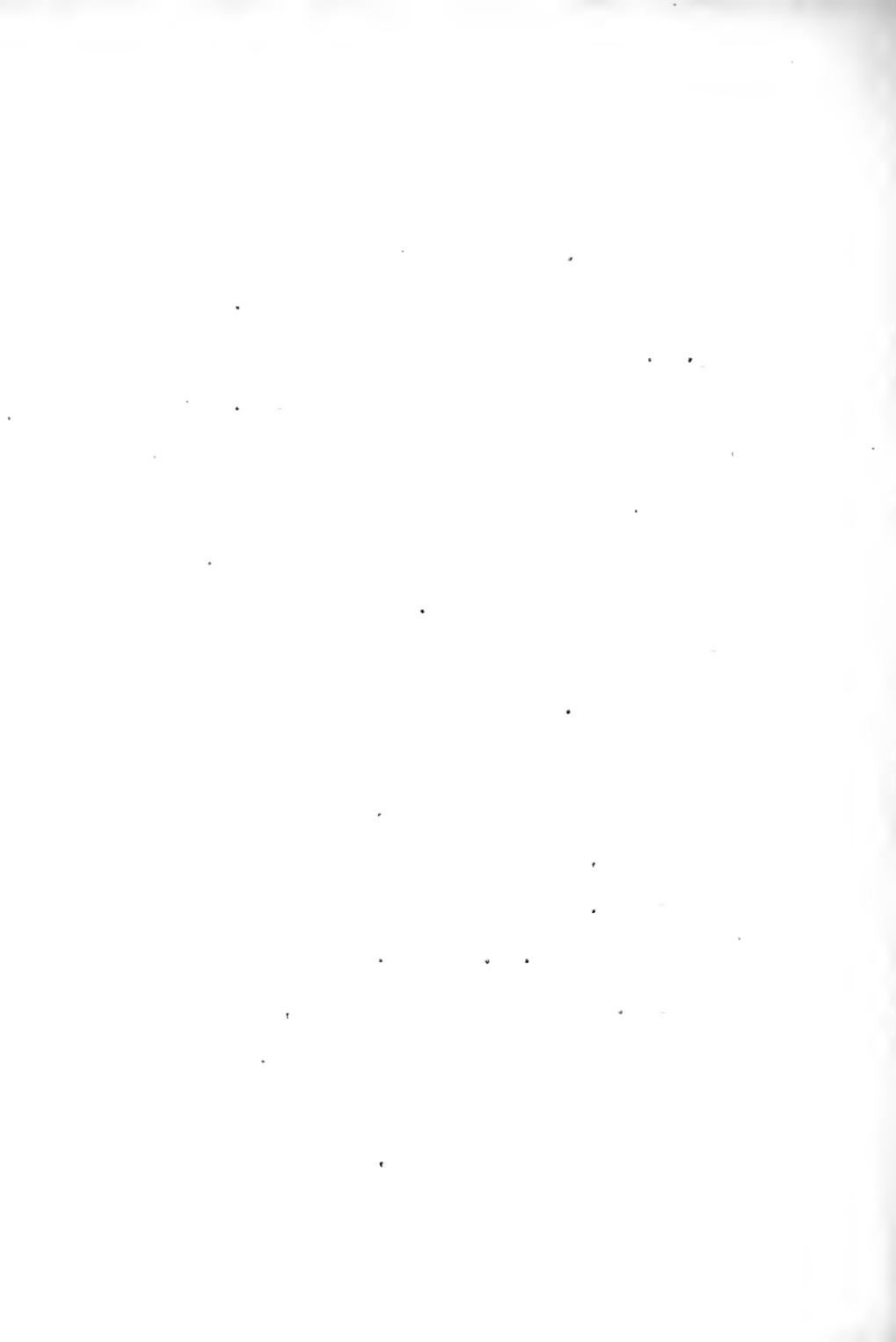
return to the use of 200 mesh iron as a carrier.

Two more conditions are as yet undecided, namely that of time and temperature at which the reaction is most favorable. The first tests were made at room temperature and covered a time of from 15 minutes to 24 hours. See Table III. The results as shown are inconsistent, they vary a great deal. It was then decided to raise the temperature at which reaction took place. Carbon bisulphide boils at  $46.25^{\circ}\text{C}.$ , benzene at  $80.4^{\circ}\text{C}.$ , and the lighter fraction of crude oil generally have their initial boiling point around  $40^{\circ}\text{C}.$ . This means that the bromination must take place at below  $40^{\circ}\text{C}.$ . Therefore  $35^{\circ}\text{C}.$  was selected as the temperature at which the reaction



should occur. For this purpose a water bath was constructed which was successful. See Fig. 1. No difficulty was had in maintaining the temperature within 1° of 35°C. Also one hour was selected as the time for reaction. The above two conditions of time and temperature gave consistent results, as is shown in Table IV. Thus two conditions were found satisfactory and thus became fixed.

The last problem was to determine the amount of bromine, and its concentration, to be used for a fixed amount of benzene. Here as in all the other tests 1/10th cc. (.0877 gm.) of benzene was used. To have a working unit, monobrombenzene was arbitrarily selected. A series of tests were then made using from 50 to 425% of bromine, calculated



on the basis of the theoretical amount of bromine required to form monobrombenzene. See Table V. The result is very interesting. It shows that in any case when less than 200% of the required amount of bromine was used about 95 per cent of this was absorbed. Also when over about 200 per cent of the required amount of bromine was used, 200 per cent of the theoretical amount of bromine required to form monobrombenzene, was absorbed. See Plate I. This is a strong indication of the formation of dibrombenzene. This practical test is thoroughly substantiated by theory. Norris<sup>1</sup> says:

"From a study of the structure of many substances formed as the result of the introduction of substituents into aromatic compounds,

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1) Organic Chemistry, p. 394.



certain general conclusions of great importance can be drawn.---- In all cases the position in the molecule taken by the entering atom or group is determined by the nature of the atom or group already present. The facts established lead to the following rules:

I. If the compound contains Cl, Br I, NH<sub>2</sub>, or a hydrocarbon radical (CH<sub>3</sub> etc.), the entering atom or group Cl, Br,I,NO<sub>2</sub>, etc., enters the position para and ortho to the group already present. In general the proportion of the para compound formed is greater than the ortho compound."

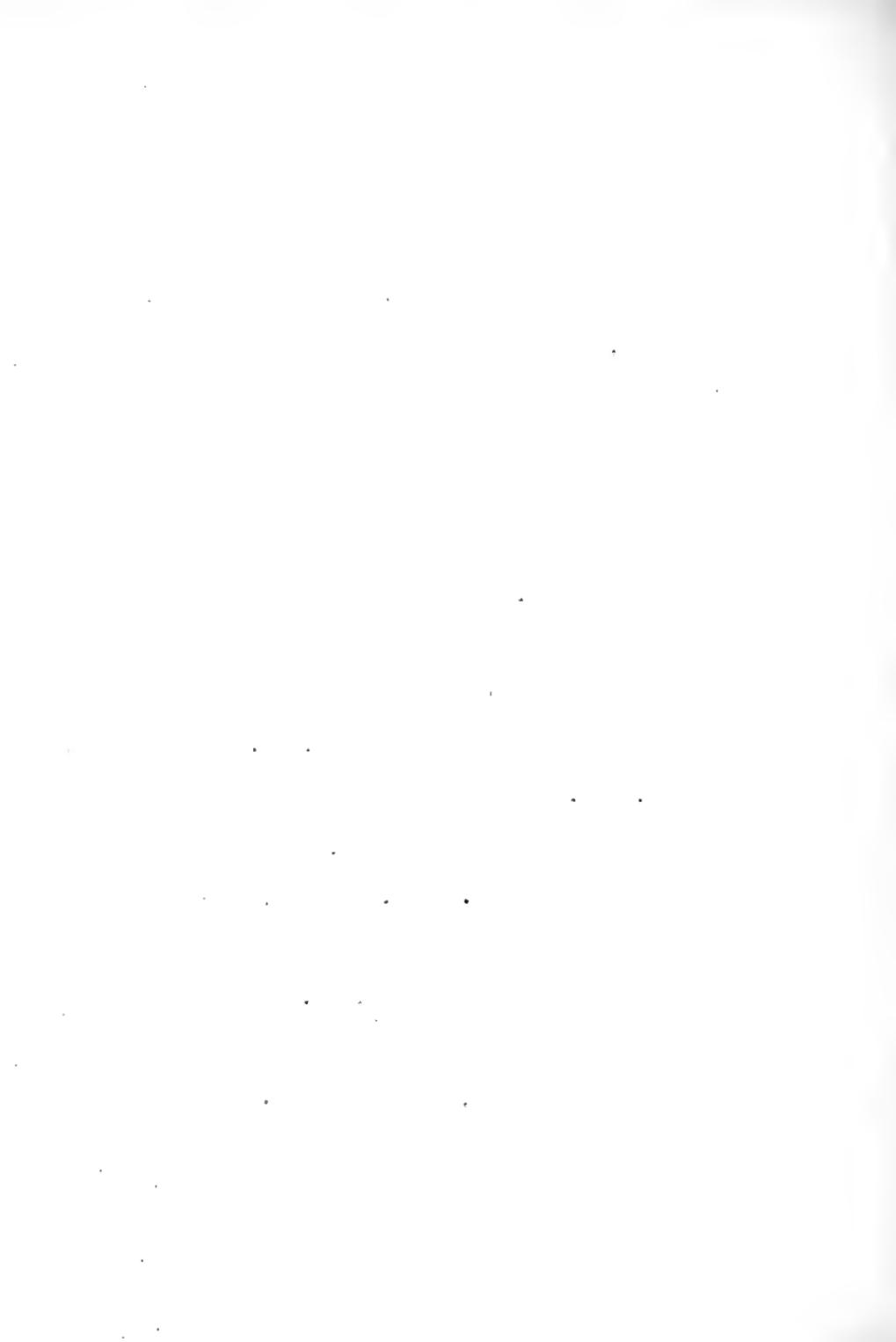
This, it seems, is sufficient proof that the final product is a dibrombenzene, the greater part being para-brombenzene and the remainder, orthobrombenzene. The conclusion is that an excess of bromine required to form dibrombenzene must be used in order to get consistent results and standardize the method.

As to the concentration of bromine used, there is no definite condition. In all the above tests made, the standard



of the various bromine solutions ranged from 1/2 normal to normal. Let it be said, however, that the better results are obtained with the more concentrated solutions. In all cases the bromine solution changes its standard from time to time and it is advised to make a blank test with each series of tests.

In summary the method is as follows:- The specific gravity of the oil to be tested is determined and .1cc. or about .1 gm. of it is introduced into the clean and dry test bottle, which already contains the .02 gm. of pure, 200 mesh iron. The author recommends the use of a bottle as shown in Fig. II. Just enough carbon bisulphide is then added to dissolve the oil, say about 5cc. Enough normal bromine solution is added



to furnish the bromine for the iron (.0579 gm. Br), and the bromine to form the dibromobenzene (.360 gms. Br.) assuming the oil to be pure benzene. This is to furnish sufficient excess of bromine. The bottle is immediately stoppered, water sealed and let stand for one hour at 35° C. A blank test should be made with every series of tests to standardize the bromine solution. At the end of one hour the flask is cooled, the stopper removed and washed, and an excess of potassium iodide solution added. The mixture is thoroughly agitated. The free iodine which was liberated by the equivalent amount of bromine not absorbed is titrated with a 1/5th normal solution of sodium thiosulphate, using starch solution to aid in the detection of the end point, which is the final disappearance of



blue color. Much agitation is necessary. Knowing the standard and relationship of the two solutions the amount of bromine absorbed is calculated. This is the difference between the amount of bromine solution used and the brom-equivalent of the thiosulphate solution, times the standard of the bromine solution. The amount of bromine reacting with the iron is subtracted from this amount. The resulting figure is the amount absorbed by the benzene and the olefines. From this is subtracted the amount of bromine absorbed by the olefines as given on page 7. The final result, the amount absorbed by the benzene is divided by 4.094, which gives the weight of benzene in the oil. With this data the percentage, by weight, of



benzene in the oil can be easily calculated.



TABLE I.

TEST NO.	WEIGHT OF PARAFFINS	BROMINE USED CC.	BROMINE WEIGHT	BROMINE ABSORBED
1	.7075 gm.	25	.189 gm.	0 gm.
2	.7075	25	.189	0
3	.7045	25	.1875	0
4	.7045	44.3	.332	0
5	.7080	27.1	.203	0
6	.7080	25	.187	0
7	.7365	25	.216	0
8	.7365	25	.216	0

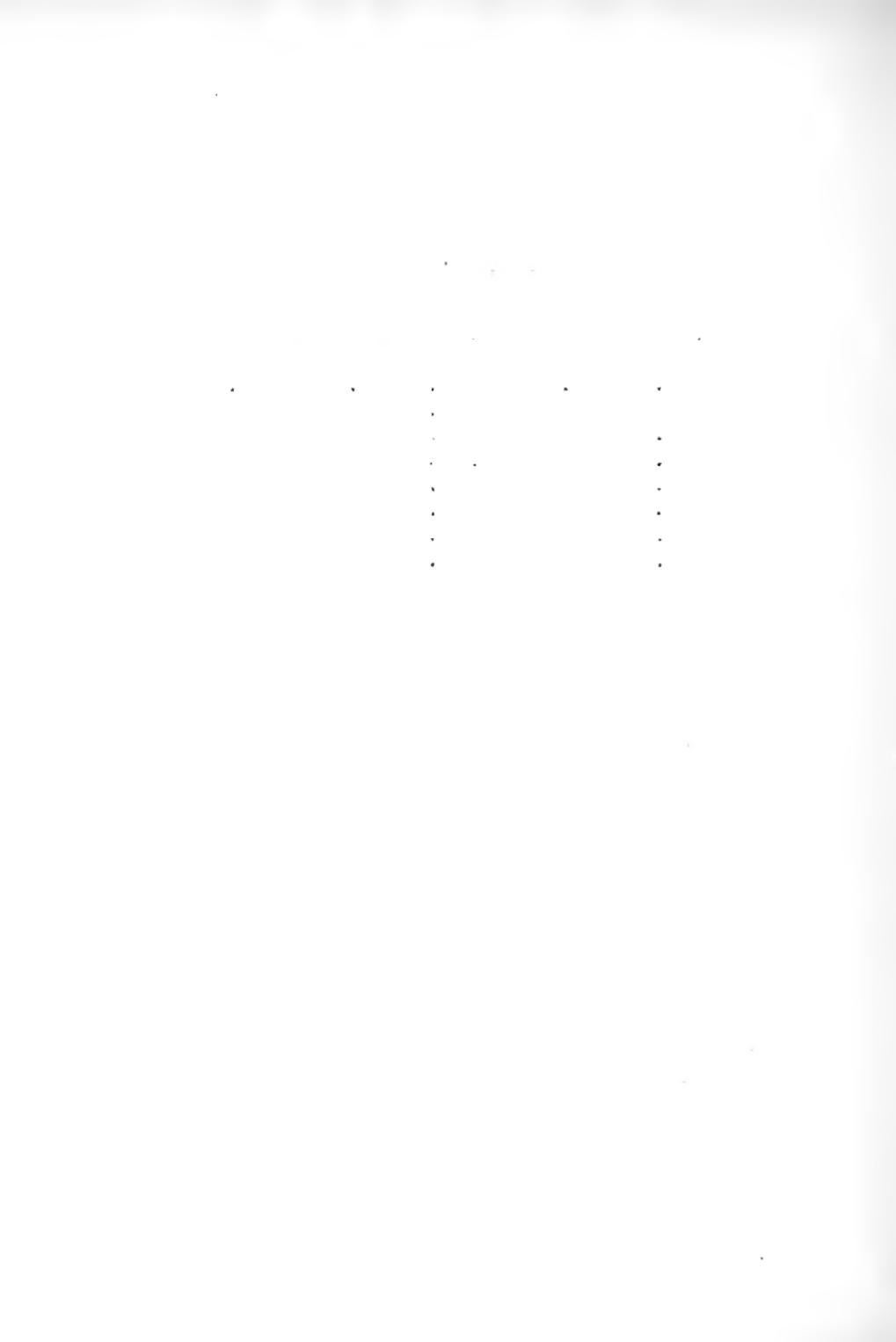


TABLE II.

TEST NO.	IRON USED	WEIGHT IRON	BROMINE USED	BROMINE ABSORBED	THEORETICAL ABSORPTION	% REACTION
22	60 mesh	.3 gm.	.216 gm.	.0942 gm.	.858 gm.	11.00%
26	"	.05	.209	.0071	.143	4.96
27	"	.05	.209	.0075	.143	5.23
28	"	.10	.209	.0054	.286	1.89
29	"	.10	.209	.0067	.286	2.34
30	"	.15	.209	.0063	.429	1.47
33	100 mesh	.05	.210	.103	.143	72.00
34	"	.05	.210	.098	.143	68.50
35	"	.05	.210	.1112	.143	77.65
36	"	.05	.210	.1071	.143	75.00
38	"	.05	.210	.1221	.143	85.50
39	"	.05	.210	.1280	.143	89.50
40	200 mesh	.05	.2085	.139	.143	97.1
41	"	.05	.2085	.141	.143	98.6
42	"	.05	.2085	.140	.143	98.0
43	"	.05	.2085	.142	.143	99.3
44	"	.05	.2085	.138	.143	96.5
45	"	.05	.2085	.141	.143	98.6



TABLE III

TEST NO.	TIME	WEIGHT BENZENE	BROMINE USED	BROMINE by C <sub>6</sub> H <sub>6</sub>	THEORETICAL 22
49	15 minutes	.8772	.2085	.024	.2085
50	"	"	.2085	.028	.2085
52	1 hour	.0877	.276	.0476	.180
53	"	"	.276	.0275	.180
54	"	"	.276	.0364	.180
55	"	"	.276	.0648	.180
57	5 hours	"	.274	.0576	.180
58	"	"	.274	.045	.180
59	"	"	.274	.0756	.180
61	24-hours	"	.270	.1007	.180
62	"	"	.270	.1295	.180
63	"	"	.270	.1142	.180
64	"	"	.270	.153	.180

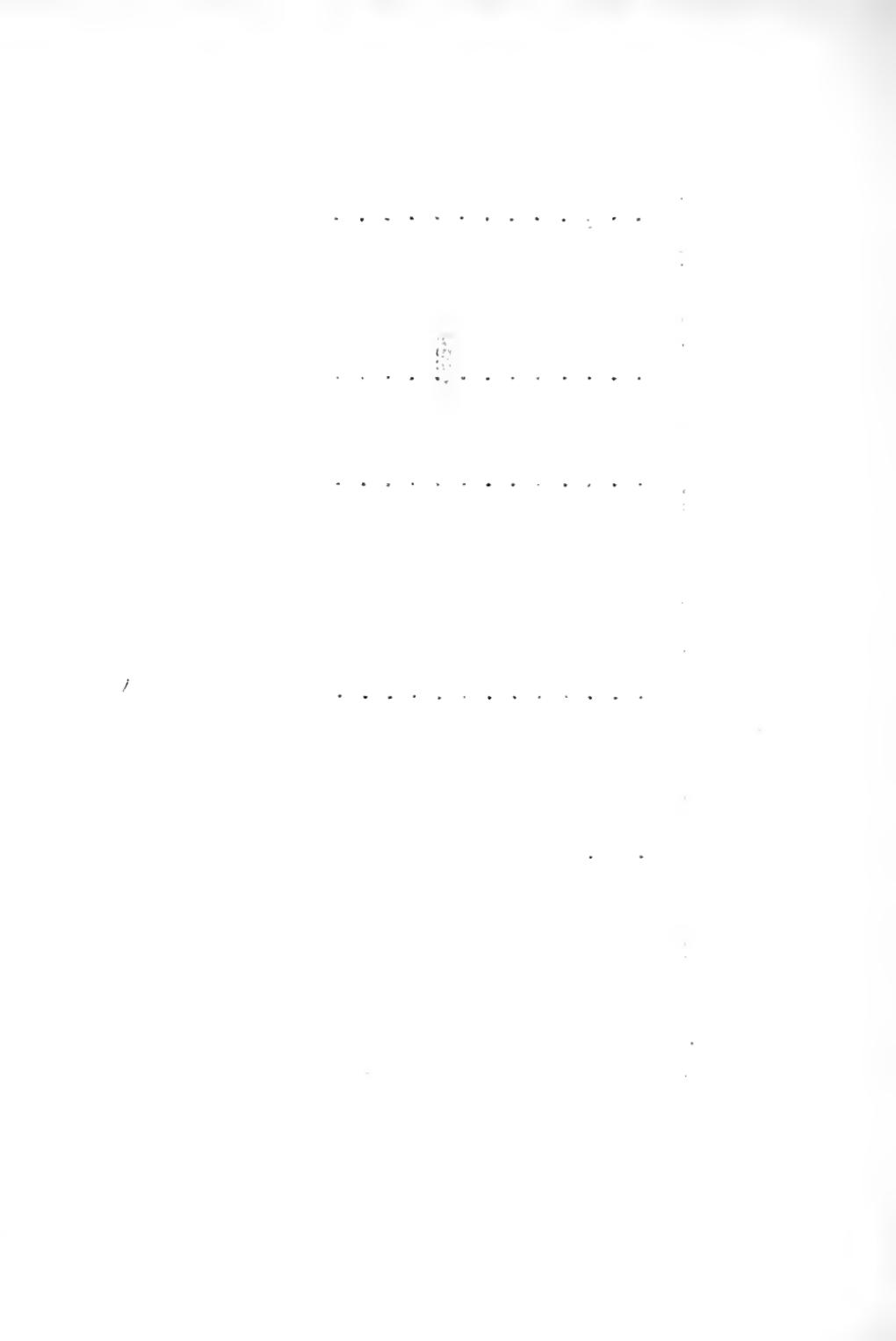


TABLE IV.

TEST NO.	BENZENE USED	BROMINE WEIGHT	USED %	BROMINE WEIGHT	ABSORBED %
66	.0877 gm.	.154gm.	85.5	.141gm.	78.4
67	"	"	"	.138	76.6
68	"	"	"	.140	77.8
69	"	"	"	.145	80.5
70	"	"	"	.140	77.8
72	"	"	"	.142	78.9
73	"	"	"	.143	79.4
74	"	"	"	.145	80.5
75	"	"	"	.142	78.9
76	"	"	"	.141	78.4
	-	-	-	-	-

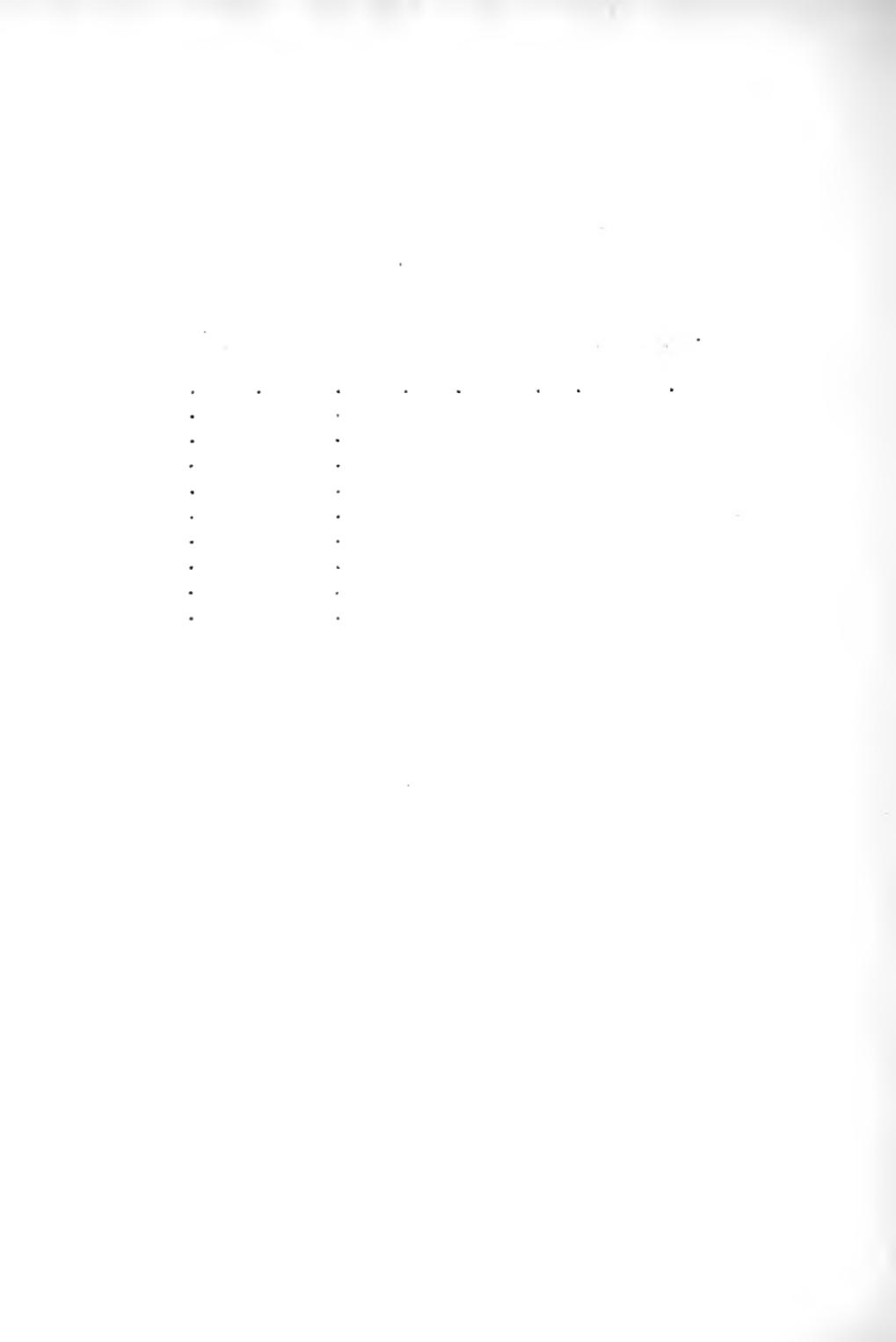
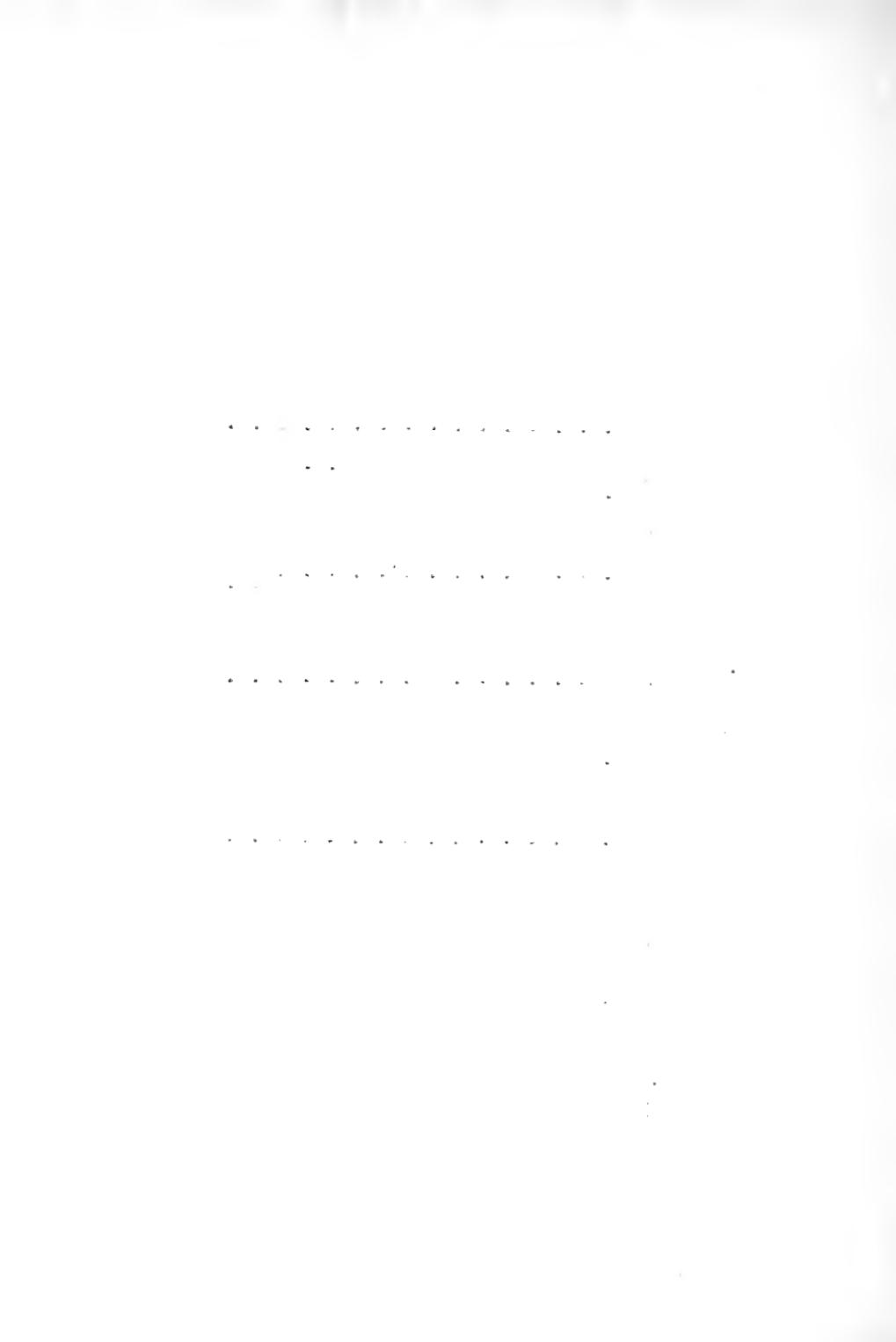
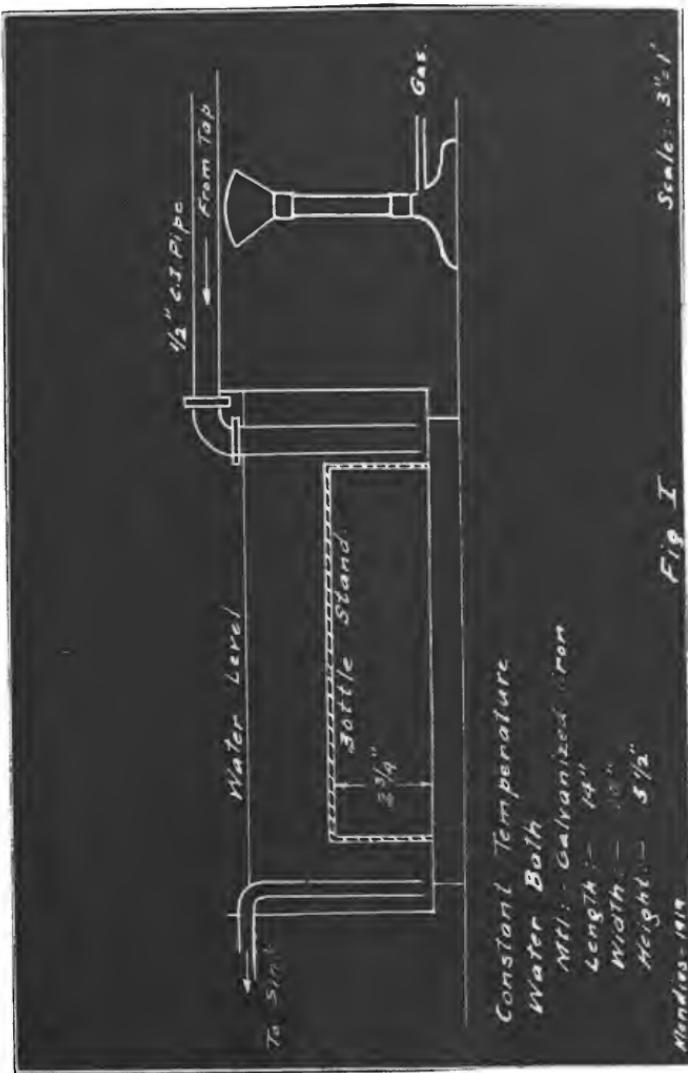


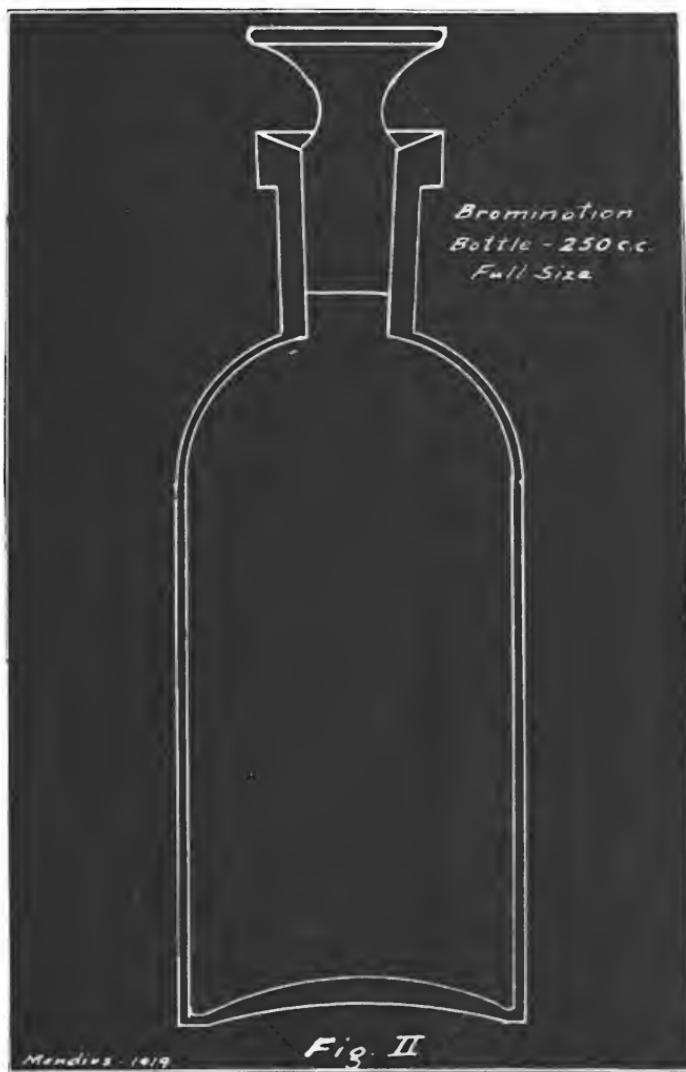
TABLE V.

TEST NO.	BENZENE USED	BROMINE WEIGHT %	BROMINE USED WEIGHT	BROMINE ABSORBED %
78	.0877	.097 gm.	.54	.089 gm. 49.5
79	"	.114	.63.3	.099 55.0
80	"	.123	.68.4	.118 65.5
81	"	.147	.81.6	.138 76.8
82	"	.154	.85.5	.143 79.6
83	"	.183	.101.5	.173 96.1
84	"	.211	.117.0	.192 106.5
85	"	.251	.128	.211 117.0
86	"	.264	.146.5	.243 135.0
87	"	.300	.166.5	.270 150.0
88	"	.321	.178.6	.298 165.5
89	"	.363	.201.0	.321 178.6
90	"	.403	.224.0	.340 189.0
91	"	.512	.284.0	.352 195.5
92	"	.561	.367.0	.3476 193.0
93	"	.759	.421.5	.353 196.0

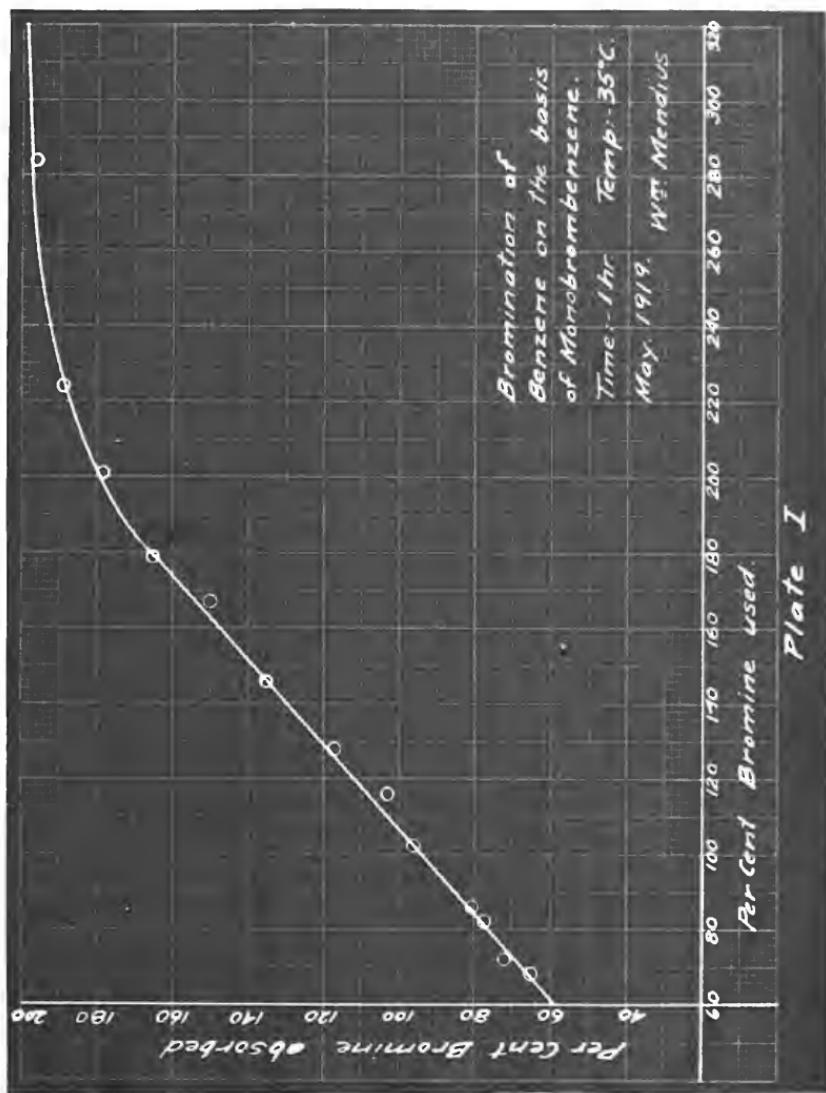














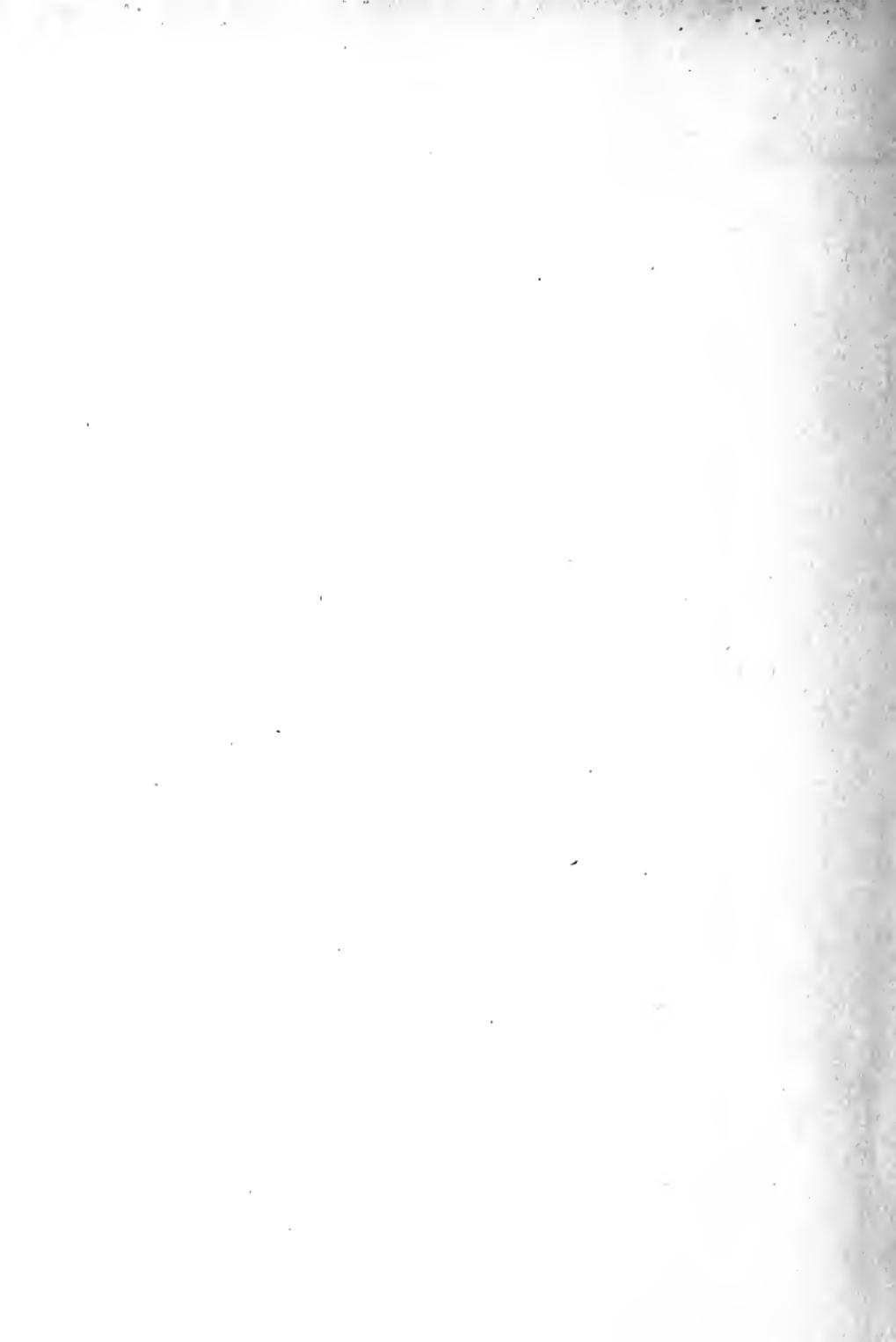


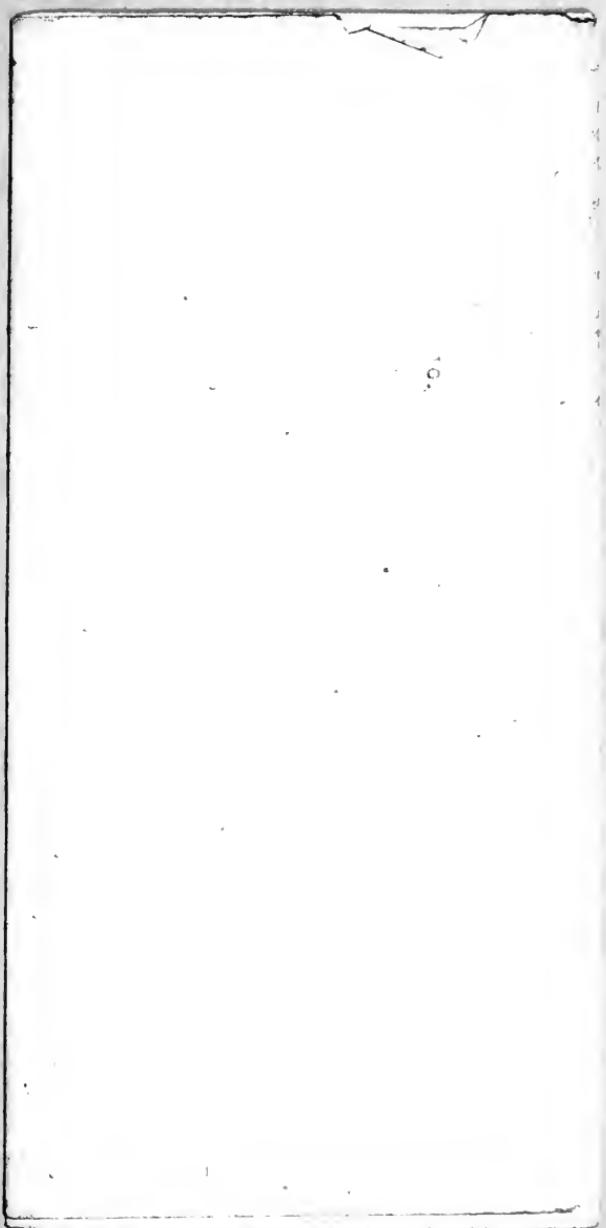












REPORT OF IRA J BELL - GEOLOGIST.

December 8th 1920.

Report of examination of the Green Bay anticline in Wisconsin.

Location.

The land examined particularly with regard to its prospects for oil, is located about the little village of Scarboro, in Kewaunee County, Wisconsin, consisting of the southeast portion of township 26 north, Range 13 east, and the west part of township 24 north, range 14 east, and the west part in Kewaunee County and covers several thousand acres of land overlaying the top of what I denominate the Green Bay structure because of its fact that it runs parallel with Green Bay struet and the other lakes northeast and southwest of it.

Topography.

The Green Bay structure is an anticlinal uplift whose western slope is marked by the line of lakes reaching northeast and southeast from Green Bay until they merge in Lake Michigan, and whose eastern slope is marked in part by the west line of lake Michigan. It is a very large uplift and it would require months of careful study and survey to determine its exact area enclosing oil collections. Inasmuch as oil is the result of the deposit of the marine life both animal and vegetable, in the bottom of the ocean while its limestone stratas are being formed and since the majority of the stratas laying under the surface in this area are ocean made deposits, undoubtedly very much oil under-this-structure was deposited in these underlying rocks as they were made, both under this structure and surrounding area and the slow uplift by which the structre was made has collected in its vacuums the oil originally deposited in the area surrounding the structure itself.

The apex of this anticlineis very easily distinguished in the localify examined and the rock structure showing along the Kewaunee, Green Bay and Western Railroad and the countour of the part of the country showa that with a little effort the apex of the anticline could be definitely ascertained within eight or ten miles of Green Bay.

The Green Bay anticline is very plainly marked showing for at least 100 miles with the usual characteristics of a great uplift having an eroded shale following with axis and parallel overlaps running in pairs parallel with its axis. The arch of the structure is so great that it is reasonable to expect a very large collection of oil and a large producing territory.

It is hard to estimate the area of the territory from which the oil which will be in the structure is collected, for the structure is ee itself is bou ded by large bodies of water which may be the syncline of this great structure or may each be the apex of another great parallel structure.

### DESCRIPTION.

There is a structure high on this anticline whose central point is about 40 rods up the stream from the little bridge at Scarboro. The stratas exposed in the little creek there shows that the anticline is a broad high uplift, and indicates a structure with a very large collecting capacity. The rocks exposed at this point are of cretaceous formation. In a well at the west side and along the bank of the stream on the east side of the store of Mr. John Hrabik oil in considerable quantities has been and is being produced. This oil is no doubt brought up by gas through crevices reaching down to an oil sand, possibly 600 feet beneath the surface, possibly coming through porous sand which makes it a distillate. I have not ~~as~~ had an opportunity to have it analyzed, but I judge it to be about 50 gravity. Its presence at this point indicates with certainty the oil escapes is right near the apex of the anticline ~~shows~~ that it comes from an anticlinal collection of oil held up under the apex of the structure, rather than a slope collection from the broken strata. In my judgement, a well drilled any place near the apex of the anticline as exposed at this point would get oil at about 600 feet, and would find oil collections in the stratas which normally would be about 1400 feet, 1500~~0~~ feet, 1900 feet, 2500 feet and ~~#~~ 3000 feet.

The location suggested above is good and if drilled to the heavy sands should get good results.

### SUMMARY.

To brief this report, the important facts are:

- 1: A well defined anticline with strata dipping both ways from its axis, with nearly equal dips, and extending over a wide area and running in the direction which the well known anticline collections bear.
- 2: A well defined anticline fold, high enough and wide enough to give great room for oil and gas accumulations with no evidence of faulting.
- 3: An anticline itself folded high, forming a "structural high" in which oil and gas may accumulate in greater quantities than ~~in~~ through the normal parts of the anticlinal structure.
- 4: An anticline occurring in an area and in formations known to contain great thickness of oil bearing rock.

### REMARKS.

In the light of these facts, I believe that the area is one that justifies the expenditure of money necessary to penetrate to the lower sands, though the production at a very reasonable depth may be found.

Respectfully submitted,

Ira J. Bell.

